GB 2292445A

(12) UK Patent Application (19) GB (11) 2 292 445 (13) A

(43) Date of A Publication 21.02.1996

(21) Application No 8217839.3

(22) Date of Filing 19.06.1982

(71) Applicant(s)
Sidney Christopher Alford

(Incorporated in the United Kingdom)

41a Pickwick, CORSHAM, Wiltshire, SN13 0HX, United Kingdom

(72) Inventor(s)
Sidney Christopher Alford

(74) Agent and/or Address for Service
Eric Potter Clarkson
St Mary's Court, St Mary's Gate, NOTTINGHAM, NG1 1LE, United Kingdom

(51) INT CL^6
F42B 1/032

(52) UK CL (Edition O)
F3A AC1A3

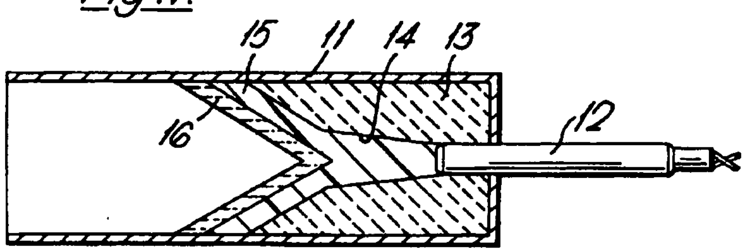
(56) Documents Cited
US 3762326 A

(58) Field of Search
UK CL (Edition E) B3W , F3A
INT CL^3 F42B

(54) Explosive cutting apparatus and method

(57) A device for generating a very high velocity liquid jet, comprising a shell (15) of high explosive material which defines a cavity and a filler (16) at least lining said cavity, the filler material (16) comprising a liquid, a gel or a non-metallic solid capable of liquefaction on detonation of the device. The material (16) may comprise water, solid hydrated salts which are soluble in their own water of crystallization on detonation, organic liquids, a fire suppressant or incendiary material.

Fig.1.



GB 2 292 445 A

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1995

1/1

Fig.1.

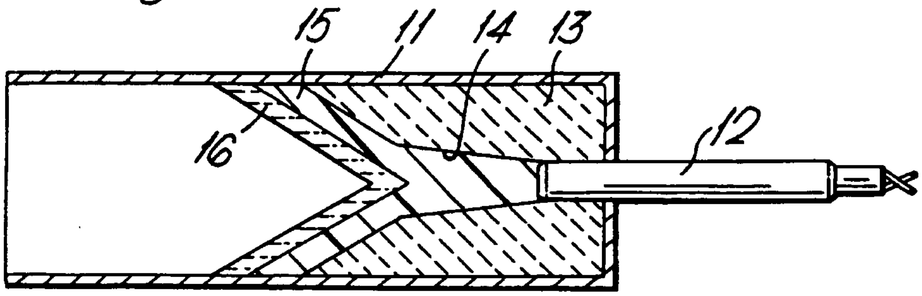


Fig.2.

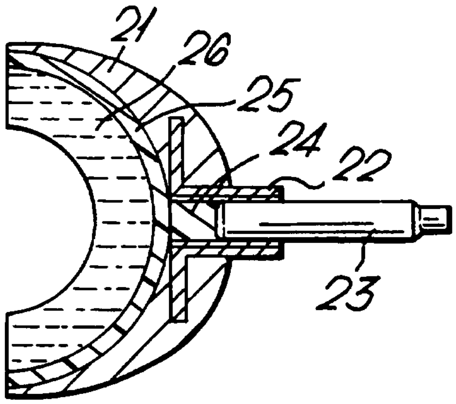


Fig.3.

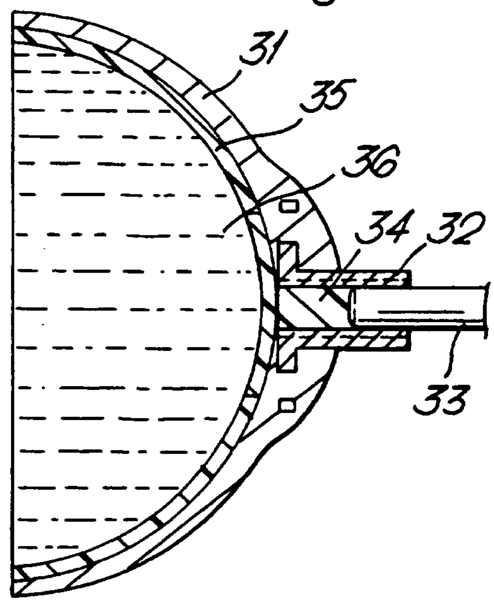


Fig.4A.

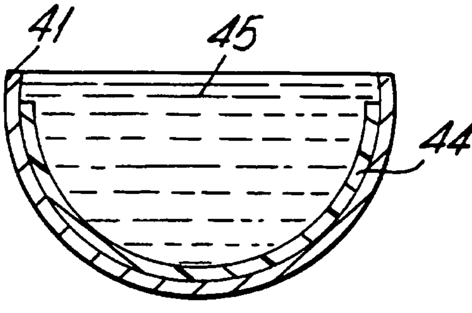
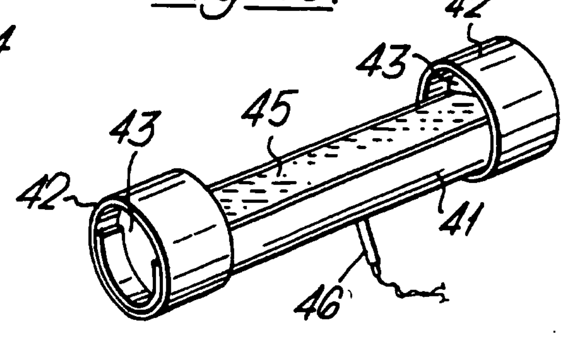


Fig.4B.



2292445

DEVICE AND METHOD FOR GENERATING A LIQUID JET OF VERY HIGH VELOCITY

This invention relates to a device and a method for generating a liquid jet of very high velocity.

There are occasions, particularly in the laboratory, when it is desired to generate liquid jets of very high velocity, such as when investigating the erosive effects of a liquid, e.g., water, on different materials, e.g., different metal alloys.

There are also occasions when it would be desirable, e.g., for reasons of safety, to be able to use a shaped explosive cutting charge which did not produce dangerous and highly disruptive jets of metal. Shaped explosive cutting charges are known which comprise a metal liner defining a cavity which is partially enclosed thereby and having explosive material around an outside surface thereof which, when detonated, causes collapse of the metal liner and the production of jets of metal of very high velocity and great penetrating power. Such known shaped explosive cutting charges are used comercially for cutting materials such as metal plates and may be used to produce cuts, e.g., linear cuts, or to punch holes in such materials either for fabricating or dismantling.

However, as stated above, the metal jets produced by the known shaped explosive cutting charges are of very high velocity and great penetrating power so that if the explosive force is not carefully matched to the target to be cut there is the danger of the metal jets produced not only penetrating the target but travelling considerable distances beyond the target, with consequent danger of damage or injury to property or persons.

The present invention has as its object to provide a device and method for generating liquid jets of high velocity and which has utility either in the laboratory or in place of the known shaped explosive cutting charges producing metal jets.

According to the present invention there is provided a device for generating a very high velocity liquid jet, comprising a shell of high explosive material defining a cavity partially enclosed thereby, and a filler material lining and optionally filling the cavity within the confines of the shell, the filler material comprising a liquid, a gel or a non-metallic solid that will liquefy upon detonation of the device.

The invention also provides a method for generating a very high velocity liquid jet, which comprises detonating the high explosive material in such a device. Preferably the high explosive material is detonated from that part of the shell closest to the innermost portion of the cavity.

As stated hereinbefore, conventional shaped cutting charges use metal liners. A cavity partially enclosed by the metal liner is essential for jet formation. The metal jets generated at the centre of the cavity upon collapse of the metal liners have high momentum and cohesiveness. The present invention has surprisingly shown that non-metallic jets, and especially aqueous jets, can be generated with much higher velocities than are usual for explosively generated metal jets, and that the filler material may completely fill the cavity in the high explosive shell. an aqueous jet generated in this manner is capable of perforating or cutting a mild steel plate. However, aqueous jets are rapidly degraded to a spray of water without producing any hazardous equivalent of the solid fragments associated with metal jets.

A device in accordance with the invention may be formed in a protective and supporting plastics container which is both cheap and light, and gives rise to no dangerous fragments upon actuation. The device may thus be made entirely without magnetic or metallic components normally with the sole exception of the detonator. It may be readily assembled by an operator, when required for use, from readily available plastic high explosive and the inert plastics components.

The device may be of a radially symmetric form, in which the shell and cavity are for example conical or hemispherical and the detonator is located on the axis of symmetry, whereby a narrow jet of liquid can be generated with the greatest penetrating power. The device may also be of elongate form, in which the shell and cavity are for example semicylindrical, whereby a liquid jet can be generated in sheet form for making a long cut across a target. Setting the device in direct contact with the target is not necessary.

An aqueous filler material is frequently preferred. Pure water can be modified by the use of additives for various purposes. Suitable additives may include anti-freezes, for example, ethylene glycol, polymeric flow modifiers such as gums to improve the cohesion of the jets, and gelling agents. Salts may be included to increase the density of the jets, and may also be used to hold the water in solid form as water crystallization; the filler material may accordingly comprise a solid hydrated salt soluble in its own water of crystallization upon detonation of the device. Some suitable salts are listed in Table I.

TABLE 1

Salt	Formula	% Water	mp (°C)	Density
Sodium thiosulphate	$Na_2S_2O_3.5H_2O$	36.3	48	1.69
Sodium sulphate	$Na_2SO_4.10H_2O$	55.9	32	1.46
Trisodium phosphate	$Na_3PO_4.12H_2O$	56.9	75	1.6
Disodium hydrogen phosphate (DHPD)	$Na_2HPO_4.12H_2O$	60.4	34-35	1.5
Magnesium sulphate (Epsom Salts)	$MgSO_4.7H_2O$	51.2	decomp 100-200°	1.67
Ammonium alum	$(NH_4)_2SO_4.Al_2(SO_4).24H_2O$	47.7	95	1.65
Potassium Alum ("alum")	$K_2SO_4.Al_2(SO_4)_3.24H_2O$	45.6	92.5	1.73

Non-aqueous filler materials may be preferred for specific purposes, e.g., a solution of zinc diethyl or aluminium triethyl in kerosine or pyrolidine, or of ethylenediamine in acetone or acetonitrile, which will react chemically with a substance contained by the target so as to neutralize the substance. Alternatively, the filler material could comprise a fire suppressant for use in siutations such as where the target is a storage tank containing a possibly inflammable substance or atmosphere.

The device may be provided with an inflammable filler material for incendiary purposes, e.g., where it is desired to burn-off the contents of a storage vessel. Suitable fillers include liquid or low melting point hydrocarbons, optionally including a thickening agent such as methyl methacrylate or soap, and finely divided inflammable metal powders such as magnesium, aluminium, or zirconium, or a material, e.g., trialkyl aluminium, which combusts spontaneously on contact with air.

A particular embodiment of the device in semicylindrical form may be used in demolition to break a structure, such as a bridge, over water. This embodiment is made up in situ using the water spanned by the structure as the filler material. A semicylindrical shell of explosive is immersed in the water with the parallel straight edges of the shell at the level of the water surface. The shell may be suspended, floated or otherwise positioned in the water beneath the structure, its longitudinal axis perpendicular to the span of the structure so that upon detonation of the charge a high velocity water jet is generated which travels upwards and cuts or breaks the structure above the device.

The shell need not be rigid for this purpose: it may be flexible or articulated so that it can be folded into a compact form for ease of transportation.

Among other possible uses of devices in accordance with the invention are the following.

Devices utilizing, for example, aqueous jellies as filler materials may be used for perforating substantial thicknesses of metal plate when it is important to prevent the secondary damage which a metal jet would be likely to cause. Among such applications might be the making of holes in submarines, or other closed vessels, in marine salvage in order to pass cables for the supply of electric power or for communication or pipes for the supply of air or other respirable gases, water, food, fire extinguishing fluids or sensors. Danger to people or equipment would be minimised, and the necessary charges much more easily transportable than conventional drilling equipment. In an analogous manner linear charges might be used for cutting larger apertures.

A hole may in particular be made in this way to accept a stud or rivet: the hole may be made by a single charge directly through overlapping sheets of metal that are to be rivetted together, and it is possible in this way to obtain a bond between the sheets even before insertion of the rivet, due to the retroflexion of the top plate into the second plate.

A device in accordance with the invention may also be used for breaking concrete or rock (including coal). An aqueous filler material may be used to combine quite high penetrating power with high and prolonged lateral forces exerted initially by shock waves and then hydraulically by the injected liquid.

The liquid jet generating devices of the invention may be manufactured with few parts, using plastics mouldings to support both the explosive and filler components. Extra mechanical strength and rigidity, as well as explosive stability may be imparted by the use of hard, extrudable explosive such as RDX-polyurethane. The devices may thereby be small and expendable and, since no expensive machining is needed, relatively cheap to produce. Their power-to-weight ratio is comparatively high, making them particularly suitable for use by divers working underwater, e.g., on oil rigs and the like.

Since the charge container disintegrates on firing, there is no need for a massive or strong support. When delivered by means of a remotely controlled vehicle an expendable wand of wood, plastics or metal suffices. If laid by hand, a light plastics tripod only is adequate. Negligible debris is generated and only light shielding needs to be provided for television monitoring camera lenses or electric lamps.

The devices may be fired electrically or by means of safety fuse. Since no metal parts need be used, the device may be made non-magnetic.

For larger versions especially, no cavity is required in the filler material. It is therefore possible to seal the jelly or other working fluid completely in a plastic capsule, thereby imparting mechanical strength, freedom from leakage, and long shelf life.

Different embodiments of the invention are illustrated in the accompanying drawings, in which:

Fig. 1 is a sectional view of a first device, having a conical explosive shell lined with aqueous jelly;

Fig. 2 is a sectional view of a second device, having a hemispherical explosive shell with a thicker lining of aqueous jelly;

Fig. 3 is a sectional view of a third device, having a hemispherical explosive shell filled with aqueous jelly;

Fig. 4a is a sectional view of a fourth device, having a semicylindrical explosive shell filled with aqueous jelly;

Fig. 4b is a perspective view of the device shown in Fig. 4a;

The device shown in Fig. 1 comprises a cylindrical plastics capsule 11 open at one end and closed at the other, except for an axial aperture for a detonator 12. The closed end of the capsule contains dry clay 13, moulded to form a conical cavity having a 60° apex angle, and with an axial passage 14 extending through the clay to the detonator aperture. The conical cavity in the clay is lined with plastic explosive 15, and the axial passage as far as the end of the detonator is filled with the same explosive, thereby separating the detonator from the apex of the conical explosive shell constituting a booster section to ensure that maximum detonation velocity is attained. A cone of aqueous carrageenan jelly 16 lines the conical cavity inside the shell of explosive.

The device is made by pressing the clay 13 in dry powdered form into shape in the capsule 11 at 400 lb/in^2 (28 kg/cm^2) by means of a steel mandrel with a conical end having a tapered axial spigot, the capsule being supported in a close-fitting cylindrical die. The clay surface is sealed and smoothed by coating with a solution of polymethylmethacrylate in methyl ethyl ketone, which is allowed to dry before the explosive is pressed into place.

The jelly lining to the conical explosive shell is formed by pouring molten jelly into the cavity, and then inserting a conical nosed mandrel the correct distance to give the desired jelly thickness. Excess jelly is ejected through a groove in the mandrel.When the jelly has set, the mandrel is removed.

The device shown in Figure 2 comprises a hemispherical cup 21 made from polystyrene resin incorporating a detonator holder 22 defining a passage through the cup along its axis of symmetry. The outward end of the detonator holder securely holds the end of a detonator 23 and the inner end is filled with a booster charge of plastic explosive 24. The cup 21 is lined with a hemispherical shell 25 of sheet explosive. A relatively thick lining of jelly 26 covers the interior of the shell; it can be cast in position, using a mandrel with a hemispherical head to form the cavity in the centre of the jelly hemisphere.

In the device shown in Figure 3, the essential difference from the Figure 2 device is that the jelly filler 36 is a complete hemisphere and fills the hemispherical explosive shell 35. The hemispherical resin cup 31, detonator holder 32, detonator 33 and booster charge 34 are all similar to the corresponding parts of the Figure 2 device.

The linear device shown in Figures 4A and 4B is formed in a plastics-impregnated paper tube cut longitudinally in a plane parallel and close (5mm away in the case of a 50mm diameter tube) to its axis. The major segment 41 is reinforced at its ends by hoops 42 which enclose and retain plastics end discs 43. The tube segment is lined with a semicylindrical shell 44 of plastic explosive and filled with aqueous jelly45.Adetonator 46 is inserted through a hole in the tube, halfway along, at the midpoint of the explosive shell, behind a booster charge of explosive.

The invention is further illustrated by the following specific Examples, in which all percentages are given by weight:

Example 1

A device as illustrated in Figure 1, in which the capsule 11 had an internal diameter of 26mm, was made using 40g. of dry clay to form the inert conical cavity, 7.5g. of plastic explosive 15 to form the conical shell and to fill the axial passage 14 and a carrageenan jelly lining 16 with a 2mm thickness.

The Explosive was PE4, consisting of 88% RDX and 12% inert plasticising oil.

The carrageenan jelly contained 2% solids and was made up of:

kappa carrageenan		16g
iota carrageenan		16g
demineralised water		1824ml
aqueous phenol	(5%)	16ml
aqueous KCl	(5%)	160ml
		2000ml

Two such devices were fired through parallel screens 30mm. and 500mm. from the charge. The time that elapsed during travel of the generated aqueous jet between the screens was estimated in each case by means of an electronic counter that was started upon perforation of the first screen and stopped upon perforation of the second. The two estimations were 25 microseconds and 33 microseconds, corresponding to jet velocities of 20 km/s (45,000 mile/h) and 15 km/s (34,000 mile/h) respectively. The aqueous jets thus approach the theoretical maximum of twice the velocity of detonation propagation in the explosive used for their generation.

Examples 2 to 5

Devices as used in Example 1 were fired against steel plates at various stand-off distances, with the following results.

TABLE 2

Example	Plate Thickness (mm)	Stand-Off (mm)	Effect on Target
2	12.7	30	7-8mm dia. round hole
3	6.3	100	3mm dia. round hole
4	6.3	150	Perforation
5	6.3	200	No perforation

In the absence of the target, the main jet generated remained cohesive for a distance of at least 500mm, and had an apparent diameter of only 6mm. Firings through screens suggested that the localised effect was exerted at a maximum distance of between one and two metres.

CLAIMS:

1. A device for generating a very high velocity liquid jet, comprising a shell of high explosive material defining a cavity partially enclosed thereby, and a filler material at least lining the cavity within the confines of the shell, the filler material comprising a liquid or a substance capable of liquefaction upon detonation of the device.

2. A device according to claim 1, wherein the filler material fills the cavity.

3. A device according to claims 1 or 2, wherein the device is protected and supported in a container.

4. A device according to any of the preceding claims, wherein the shell and cavity are of a radially symmetrical form, and wherein a detonator is located on the axis of symmetry, whereby in use a narrow jet of liquid is generated.

5. A device according to any of claims 1 to 3, wherein the shell and cavity are of elongate form, whereby in use a jet of liquid in sheet form is generated.

6. A device according to any of the preceding claims, wherein the filler material is of aqueous form.

7. A device according to claim 6, wherein the filler material comprises a combination of water and additives.

8. A device according to claim 7, wherein the filler material comprises a solid hydrated salt soluble in its own water of crystallization.

9. A device according to any of the preceding claims, wherein the filler material comprises a fire suppressant.

10. A device according to any of claims 1 to 8, wherein the filler material comprises an inflammable material.

11. A device according to claim 6, or any claim appended thereto, wherein the shell is semicylindrical in

form and the filler material is an expanse of water in which in use the shell is immersed with the parallelstraight edges of the shell located substantially at the level of the surface of the water, whereby upon detonation a water jet is generated generally upwardly from the surface of the water which jet can be used to demolish a structure spanning the water and under which the device is located;

12. A method for generating a very high velocity liquid jet comprising the steps of forming a shell from a high explosive material, thereby defining a cavity partially enclosed by the shell, at least lining the cavity within the confines of the shell with a filler material comprising a liquid or a substance capable of liquefaction upon detonation of the explosive material, and detonating the explosive material.

13. A method according to claim 12 and comprising the further step of detonating the explosive material from that part of the shell closest to the innermost portion of the cavity.

14. A device for generating a very high velocity liquid jet, substantailly as herein described with reference to Figure 1, Figure 2, Figure 3 or Figures 4a and 4b of the accompanying drawings.

15. A method for generating a very high velocity liquid jet, substantially as herein described with reference to Figure 1, Figure 2, Figure 3 or Figures 4a and 4b of the accompanying drawings.

Amendments to the claims have been filed as follows

CLAIMS

1. A device for generating a very high velocity liquid jet, comprising a shell of high explosive material defining a cavity partially enclosed thereby, and a filler material at least lining the cavity within the confines of the shell, the filler material comprising a liquid, a gel or a non-metallic solid that will liquefy upon detonation of the device.

2. A device according to claim 1, wherein the filler material fills the cavity.

3. A device according to claims 1 or 2, wherein the device is protected and supported in a container.

4. A device according to any of the preceding claims, wherein the shell and cavity are of a radially symmetrical form, and wherein a detonator is located on the axis of symmetry, whereby in use a narrow jet of liquid is generated.

5. A device according to any of claims 1 to 3, wherein the shell and cavity are of elongate form, whereby in use a jet of liquid in sheet form is generated.

6. A device according to any of the preceding claims, wherein the filler material is of aqueous form.

7. A device according to claim 6, wherein the filler material comprises a combination of water and additives.

8. A device according to claim 7, wherein the filler material comprises a solid hydrated salt soluble in its own water of crystallization.

9. A device according to any of the preceding claims, wherein the filler material comprises a fire suppressant.

10. A device according to any of claims 1 to 8, wherein the filler material comprises an inflammable material.

11. A method for generating a very high velocity liquid jet comprising the steps of forming a shell from a high explosive material, thereby defining a cavity partially enclosed by the shell, at least lining the cavity within the confines of the shell with a filler material comprising a liquid, a gel or a non-metallic solid that will liquefy ~~or a substance capable of liquefaction~~ upon detonation of the explosive material, and detonating the exposive material.

12. A method according to claim 11, wherein the shell is semicylindrical in form and the filler material is an expanse of water, comprising the steps of immersing the shell in the water with the parallel straight edges of the shell located substantially at the level of the surface of the water and detonating the explosive material, whereby a water jet is generated generally upwardly from the surface of the water which jet can be used to demolish a structure spanning the water and under which the device is located.

13. A method according to claim 11 or 12 and comprising the further step of detonating the explosive material from that part of the shell closest to the innermost portion of the cavity.

14. A device for generating a very high velocity liquid jet, substantially as herein described with reference to Figure 1, Figure 2, Figure 3 or Figures 4a and 4b of the accompanying drawings.

15. A method for generating a very high velocity liquid jet, substantially as herein described with reference to Figure 1, Figure 2, Figure 3 or Figures 4a and 4b of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 8217839.3

Relevant Technical fields

(i) UK Cl (Edition E) F3A, B3W

(ii) Int Cl (Edition 3) F42B

Search Examiner

R C KENNELL

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

29 JUNE 1983

Documents considered relevant following a search in respect of claims

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	US 3762326	

SF2(p)

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).